9/3/52 Total Perfusion

Purpose - To effect the extra corporeal oxygenation of the dog's circulation with an attempt of survival.

OP. Dog.# 159 - 18 Kilo Male.
Donors and Op. dog cross matched. Compatible. (35 mgm. heparin per 1 liter of donor blood used)

Procedure: The femoral vessels exposed in usual manner. Chest was opened on the right side only.

11^{24} Chest open.

12^{15} Art. strain gauge in AP 180/130 VP 11 mm Hg.

1^{09} SVC cannula in AP 180/130

1^{10} Respirator failed- not recognized at first - AP up to 250/150

1^{13} Respirator repaired. AP 119/150

1^{25} Partial perfusion (SVC only) started AP dropped to 120/80 in a period of three minutes. Flow 800 cc/ min.

1^{28} Flow 500 cc/min. AP 180/100

1^{30} IVC cannulated

1^{32} Flow 1300 cc - 6 discs on AP 150/80

1^{34} SVC and IVC tied around cannulae. Flow 2000 cc/min. AP 140/70

1^{35} Respirator was turned off. Flow 2200 cc/min. Poor oxygenation pH 7.06

1^{36} 50 cc of $NaHCO_3$ given rapidly. AP 130/70- Flow 2200 cc/min.

1^{41} Flow 2400 - AP 125/65 Neo-S slow drip on.

1^{46} $NaHCO_3$ slowly in.

2^{00} SVC tie loosened. Flow 1700 cc AP 140/70 - VP 14 mm Hg

2^{01} IVC tie loosened. Flow 1500 cc respirator on. AP 140/70

2^{05} IVC cannula out. AP 175/125

2^{11} Flow 1000 cc AP 160/125 VP 14 mm Hg.

2^{15} SVC cannula out. Stop perfusion AP 175/80

2^{20} AP 200/125

Chest closed in usual manner. Dog in poor condition. Very little bleeding into the chest.

7^{30} P.M. Dog awake.
During the night: Dog on continous suction applied to the righ chest cavity. 250 mgm. terramycin Q4H IV
$NaHCO_3$ 20 cc Iv

Continuation of 9/3/52

700 cc NaCl IV - Oxygen via catheter
500 cc 5% G/W in the morning.
This dog had (MS ½ gr. Q4H during the night.
& 1/50 gr. SAS)
In the dog up and about taking milk by mouth. Continued on antibiotics Returned to cage at night. Dead in morning. Post mortem showed pleural effusion and massive pneumonia more on the right side. This dog had distemper to start with.

Observations: Team work was running smoothly. It seems to be advantageous to open the right chest only. It means less surgery and so far less post op. bleeding. Post operative care seems to be of vital importance. We feel that having a healthy dog to start we would have had a permanent survival. This dog was alive for 40 hours after perfusion. This time we used less heparin (20 mgm less) and we had no clots on the machine.

Lab. Data

Sample	corr. pH	Hmtcr	Hgb	Pl. Hgb	SH	SV
Donor res	7.41	47%	14.4 g%	278.3	103	
Op. contr	7.21	42	14.1	10.8	91	
3 min	7.06	48			89	62
15 min	7.17	44		211.2	89	50
30 min						
End perf	7.25	41	13.5	72.6	99	48

Prot. titr:

Clotting time

sample:	0 time	A	B	C	clotting
Contr	0	15	20	21	21 min

15 γ/cc - clot. time 8 min

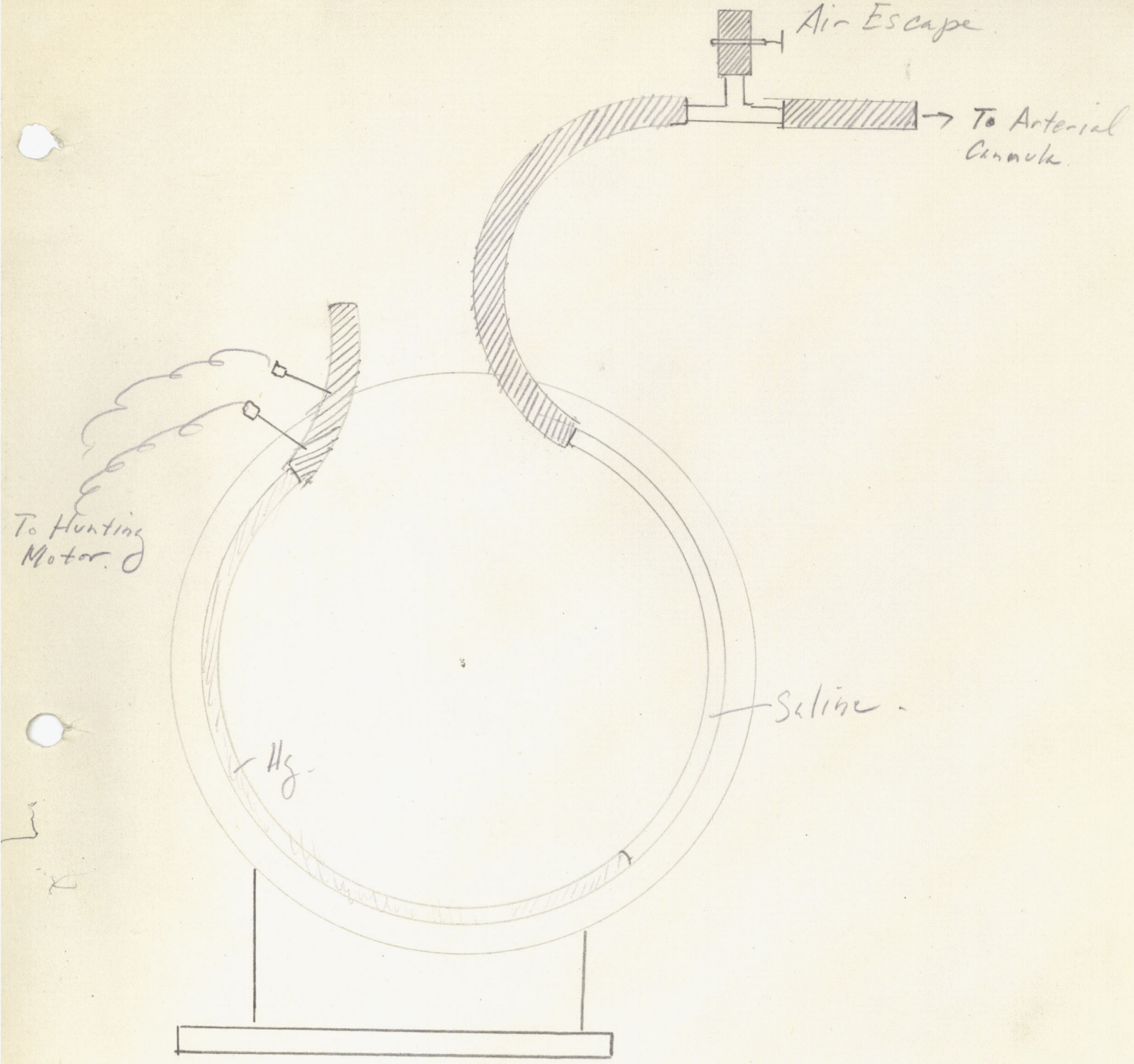
total 2 cc prot.

Formatin test:

negat.

9/10/52 Total Perfusion

Purpose: same as 9/3/52
Procedure: Same as 9/3/52
Op. dog #162 17 Kilo and donors cross matched. Found compatible (MS and HS used.)
This dog was cannulated as on 9/3/52. Femoral arteries were very small in this dog and only a small return cannula could be used. No adequate arterial return could be obtained during the course of the perfusion. The machine worked satisfactorily. In conclusion the experiment was a failure. In the future it would be advisable to return the blood through both femoral arteries and record the arterial pressure from the internal mammary artery.

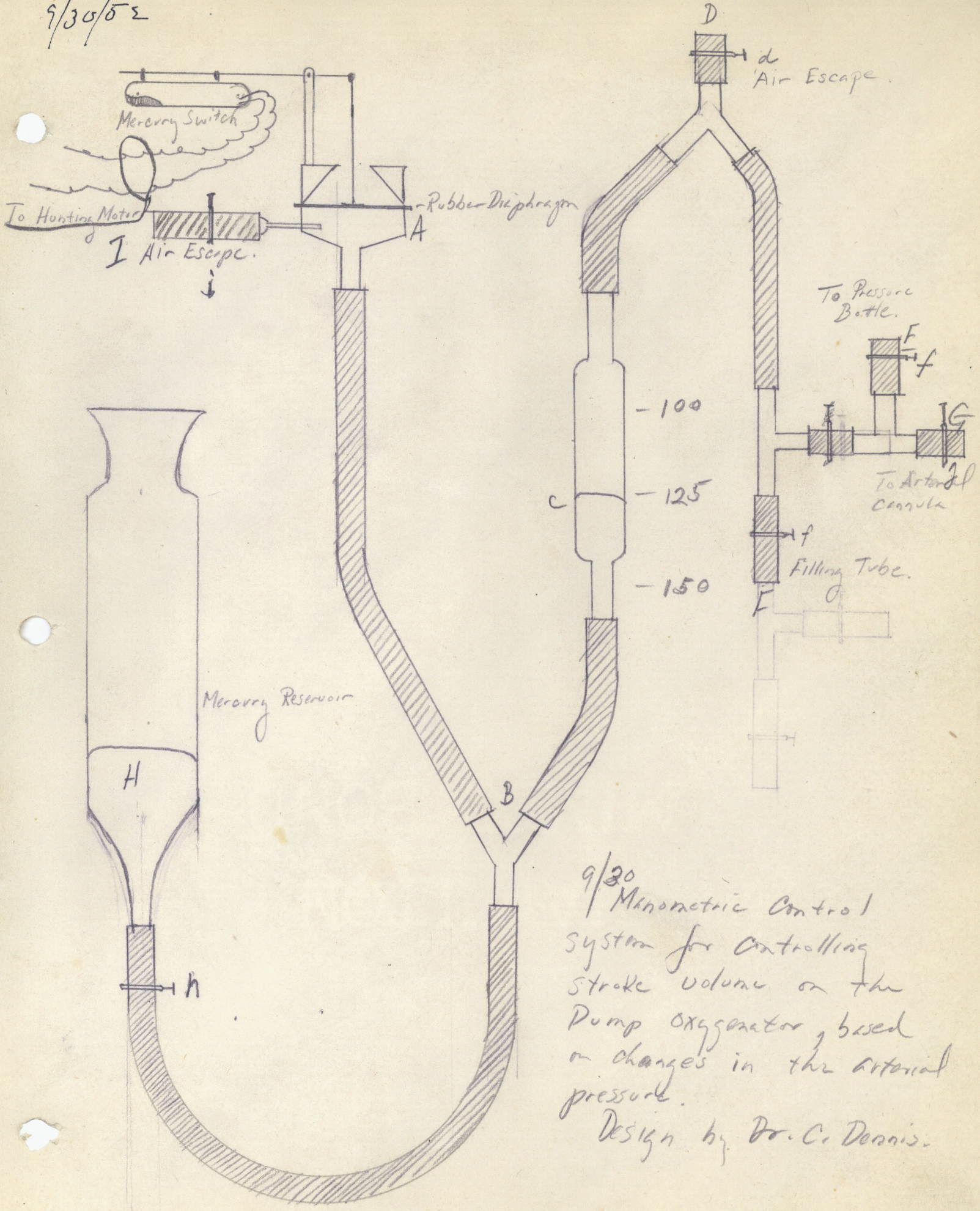


9/25/52 Mechanism for Controlling the Stroke Output of the Pump-Oxygenator by the Arterial Blood Pressure of the Patient.

As the blood pressure of the subject increases, the mercury rises in the left hand column closing the electrical contacts in the rubber tubing. This is connected to the Hunting Motor relay causing the stroke volume to decrease. When the patient's blood pressure decreases, the mercury column falls away from the contacts and the current is opened reversing the relay and causing the Hunting Motor to increase the stroke vulumn. In this manner itwas hoped that the blood pressure of the subject could be maintained at a constant predetermined level. The device was mounted on a wheel in order to facilitate changing the desired arterial pressure; rotating the wheel clockwise would set the pressure at a higher level, counter-clockwise, at a lower level.

This device did not work because there was no damping mechanism in the system, the pulse shooting the mercury out of the tube.

9/30/52



9/20 Manometric Control System for Controlling Stroke Volume of the Pump Oxygenator, based on changes in the arterial pressure.

Design by Dr. C. Dennis.

9/30/52

Hunting Motor Control for Pump-Oxygenator

This device schematically illustrated on the previous page was designed to regulate the arterial stroke volume by the arterial blood pressure of the subject. It was designed to provide the damping effect that was lacking in the design of 9/25/52. The U-tube ABC is filled with mercury from the mercury reservoir H by opening clamp ch and by allowing air to escape through tube I. All air must be removed from under the rubber diaphragm. The pressure at which the mercury switch will be opened or closed will depend upon the height of the mercury column BC. The remainder of the closed system is filled with sterile saline, all air being removed from the tubing.

Calibration: The device is calibrated by filling the system as described and by attaching a mercury manometer to E,F, or G. and placed at the same level as that ordinarily occupied by the patient. By increasing the pressure within this system with a syringe filled with saline and attached to E,F or G, it is possible to produce various pressures as determined by reading the mercury manometer. For any given pressure on the manometer it will be possible to alter the amount of mercury in the mercury column ABC so that the mercury switch will just trip at that pressure. A mark is placed along the column BC for that pressure. This is repeated for several different pressures until a sufficient number of points are obtained.

Operation: The device is filled as decribed after being sterilized with formaldehyde solution overnight. The device is set for any desired mean arterial pressure by allowing Mercury from the reservoir H to flow up to the proper mark on column BC.

10.1.52 Total perfusion

Purpose:Perfection of the teamwork.

Procedure:As usual - with operative approach through the right chest only.

Donors: #156 - 17 Kilo - 1000 cc blood
#164 - 13 Kilo - 850 cc
#160 - 13 Kilo - 600 cc

The bleeding was performed under local anesth.using 1% procaine The dogs were heparinized previously to bleeding using 3 mg/Kg. This was performed in order to eliminate the amount of Nembutal from the doner blood to avoid the excessive depression of the op.animal.

Op.dog: #163 - 22 Kilo
Nembutal anesth.25 mg/Kilo I.V.
MS gr.1/4 AS gr.1/50
After the femoral arteries were exposed and the chest opened the dogs respiration became tugging.It was noted that the endotracheal tube became dislodged with the respirator.The dog was given MS gr.1/4 in an attempt to quiet down his respiration with no successThe dog died on the table mainly because of severe anoxia.The inspection of the Dennis respirator showed the main flapp valve not closing properly.

Autopsy findings:Pulmonary edema and acute dilatation of the heart.

Consequently the respirator was rebuilt.Serious consideration was given to the possibility of discontinuing the use of the respirator.

X-matched - OK

October 2,1952

IVC not encannulated

Total Perfusion.

Purpose: To investigate a new method of controlling the arterial output of the pump oxygenator by means of a device which would regulate the stroke volume of the arterial pumps in accordance with the arterial pressure of the dog.

Dog: # 119 - 15 Kg.

Following the unsuccesful attempt at perfusion on the previous day, it was decided to perfuse an animal on 10.2. Donor blood which had been drawn on 10.1. was used for this experiment. The blood was stored in the refrigerator after adding 250 mgm. Terramycin in to each liter.

Premedication: MS gr.1/4 AS gr.1/50
IV Sodium nembutal 7.0 cc

Procedure: Dog positioned on left side c. right side up. Femoral vessels isolated in usual manner. Chest entered after removing 4th rib. Azygos vein, SVC, IVC dissected free. Pericardium opened. I.V. infusion begun in rt. femoral vein - 5% Glucose. 1.5 cc heparin administered.

12.05 - Rt. femoral artery cannulated and connected to Strain gauge BP 140/100
12.30 SVC cannulated BP 120/90
12.45 Arterial pressure control mechanism connected BP 160/110
12.49 Machine on BP 110/75
Flow 500 cc. Art. pressure vacillating markedly, varying from 205/175 to as low as 90/65. Art. control mechanism set at 125mmHg
12.53 Flow 1500 cc/min BP 175/120 - 120/60
12.54 Flow 1000 cc/min. Level in the machine high. Venous stroke decreased.
12.56 Flow 1200 cc/min. BP steady at 150/95. Subsequently arterial pressure began fluctuating and fell to 100/60. It was noted that the level in the cup had fallen to the point where air had been introduced into the arterial cannula, while the level in the U tube level indicator was still high. The solenoid did not function. A clot had formed in the tubing connectir connecting the level indicator to the collecting cup. Machine chut off. Bubbles aspirated from arterial tubing. BP fell from 160/125 to 90/65
1.00 BP stabilized at 140/100
1.02 Machine on.
1.05 Flow 1500 cc/min BP 140/100
1.10 Rt. atrium opened. However, the IVC was not cannulated, because it was believed that the animal had suffered air embolism.

From 1.05 to 1.21 BP maintained constant at 150/100
1.21 Machine off. Rt. atrium closed, cannula removed from SVC, azygos ligated. Art. cannulas removed. Wounds closed in layers.
1.50 3 cc protamine given I.V.

Post.op.: weight: 17 Kilo
250 mgm Terramycin I.V.q.4 h.
5.25 525 cc blood aspirated from chest.
6.05 120 cc aspirated from chest

Dog expired at 6 AM the following day.
Autopsy - gross - Moderate atelectasis rt.lung. No air found in coronary arteries.
Micro: Emphysema, pulmonary congestion.

Sample	Corr pH	Hmtcr	Hgb	Pl. Hgb	S_A	S_V
Dom. Res	7.38	42	13.3	106.8	95	
Op. Cond	7.34	47	15.0	7.8	92	
3 min	7.54	37	12.6	90.0	104	88
15 min	7.54	40		102.0	89	62
End	7.45	43	14.4	126.0	102	71
1 mon.	~~7~~			246.0		

Prot. titr:

20γ/cc (cl.-ft. time 19 min)

total 3.2 cc

Formolin test:

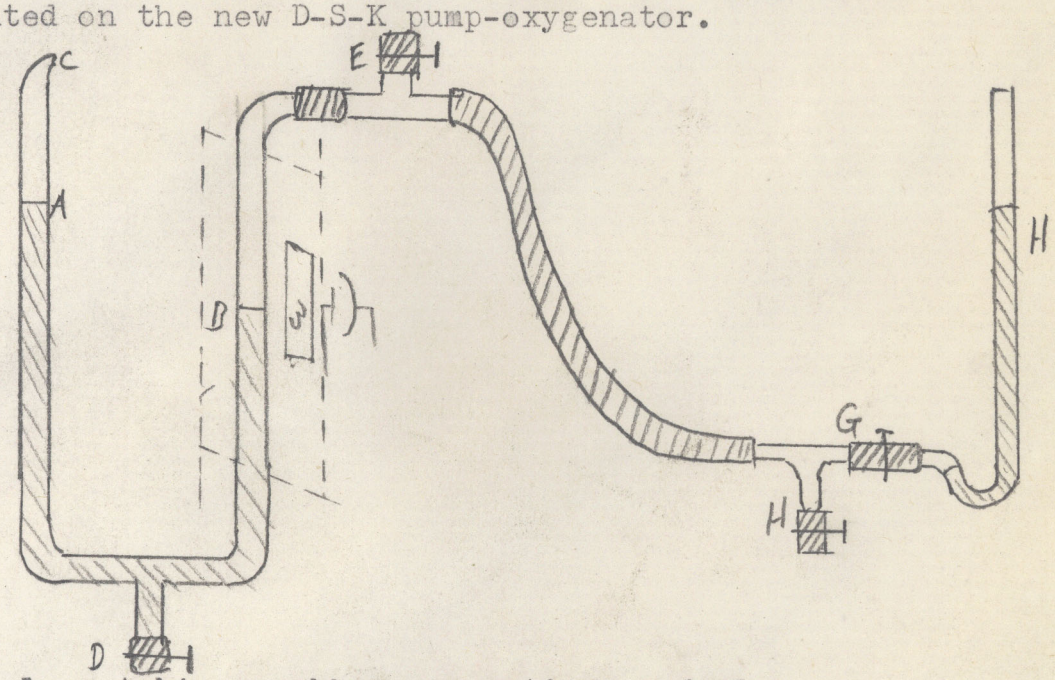
negative

10/7/52

METHOD FOR CONTROLLING ARTERIAL PUMP MOTOR SPEED BY THE LEVEL OF THE ARTERIAL BLOOD PRESSURE OF THE SUBJECT.

Purpose: The purpose os to develop a manometric system applicable to the sensing unit of the Shoenfeld modification of the Enslein electronic control unit mounted on the new D-S-K pump-oxygenator.

Method:



A system of glass tubing, rubber connections and clamps was constructed as illustrated above.

The arm of the U-tube, B, was mounted in the slot provided in the sensing unit of the Enslein control circuit, so that the tubing was in front of the photoelectric tube window, W. For the purpose of this experiment the critical level photoelectric tube was not used.

A small air vent, C, is at the upper end of arm, A, for the purpose of damping the swing of mercury due to the arterial pulse. Arm D is for the purpose of draining mercury. Arm E is used to admit mercury to the system and to let out air trapped in the system. The apparatus is sterilized with 3% formalin by admitting the solution through arm F or G. and connections clamped. After calibration, the mercury manometer H is removed. Before use a sterile wash battle is connected to opening F and the connection G is connected to the glass adapter deading to the arterial cannula. (The tubing may be connected by means of a T-tube to the same cannula used for the strain gage.)

Calibration:

The U-tube is filled with mercury through E and the system is filled with 3% formalin, with a mercury manometer H attached as shown. A syringe filled with 3% formalin is attached to F and pressure applied to the system until the manometer H reads 125 mm Hg. when the manometer H is placed on the OR table (same level as the subject) The U-tube is shifted up or down so that the level of the mercury B is at the same level as the middle of the Photoelectric tube window W. The Manometer H is then removed and the tube clamped.

The appratus is now calibrated for operation at 125 mm Hg mean arterial pressure.

Operation: The the Thy-Mo-Trol poteniometer 3P set as low as possible, and the 4P potentiometer of the Enslein circuit properly set for full range of response by the sensing unit, the arterial side is set to run at a moderate rate, allowing for a sufficient range above and below this basic rate.

The pump stroke on t e arterial side must then be set manually so that the actual amount of blood returned will be just sufficient to cause a rise in the arterial pressure when the motor speeds up and a fall when it slows down.

Conclusions: Preliminary studies with this apparatus using water and syringe to simulate arterial pressures and pulsations indicated that the response of the Thy-Mo*trol motor was satisfactory.

Further studies with this apparatus are justified and this method will be used in the next perfusion.

October 21, 1952

Effect of Aqueous Extract of Dried Nylon Glue on the Dog When Given Intravenously.

Purpose : It was noted that the Nylon Glue, wsed in plugging the bases of the Nylon shuttles made for the DSK heart-lung machine, appeared to soften and spread when autoclaved. The purpose of this experiment is to determine if any soluble substances are present in the glue which might be deleterious to the perfused subject.

Method: One gram of DuPont Nylon Glue was dissolved in 1/4 gram of the solvent, placed in a drying oven until all the volatile material was evaporated. The dried glue was mixed with distilled water and boiled slowly for approximately five hours. The flask was then placed in a refrigerator for reheating the next day. The following momorning the material was boiled slowly for an hour, filter hot, and sterilized by boiling for 20 minutes.

The material was then injected into dog #8, a 10 kgm. Mongrel aseptically. 5cc was injected intravenously at 11:10 AM. The solution was light amber in color and clear.

	Control Blood	Sample at 3 hr.	Sample at 5 hrs.
WBC	12,700	9,900	12,000
RBC	5.75 million	7.07 million	6.83 million
Differential 100 cells counted			
Polys	52	67	65
Lymphs	32	27	25
Eos	4	0	0
Baso	1	0	0
Monos	11	1	10
Platelets	Adequate	Adequate	Adequate

The serum of the control blood was clear, except for a small amount of hemolysis. The serum of the 3 hr. sample was very turbid, with a very slight amount of hemolysis. The dog had not eaten, but the serum appeared very chylous. The serum of the 5 hr. sample was slightly less turbid and there was no hemolysis.

Clinically the dog appeared normal.

Proteins Studies:

	Albumen	Total	A/G Ratio
Control	2.95	7.15	0.70
3 hour	2.39	7.50	0.58
5 Hour	2.30	6.65	0.53

It was also observed that the smears used for the differential white cell count had a very bluish background often seen when the globulins are high, so it was not surprising when the high globulins were reported. There was no rouleaux formation.

Summary and conclusions:

1. The turbidity of the serum following injection of the extract is unexplained, nor are the results of the protein studies.
2. Inasmuch as the dog remained well clinically in spite of the fact that it received a large amount of the extract, the glue is considered safe for use on the shuttles.

DSK Pump Oxygenator 1952

By the first of May,1952 the project to construct the new Pump Oxygenator had progressed beyond the planning and purchasing phase and construction begun.

The basic problem was to produce a machine that could be autoclaved.All metallic parts coming in contact with blood were made of stainless steel(Type 303) because previous tests demonstrated that other substances were unsuitable,either because they were toxic or could not withstand autoclaving(Kell-F,Nylon,Teflon)

The general principles of the machine are essentially the same as those in the old machine except for the independent drive mechanisms for the arterial and venous pumps.The control mechanism is entirely different.In this machine it is possible to alter the stroke volume by changing the stroke length manually on either the arterial or venous sides.The speeds of the arterial and venous pump motors can be controlled manually.In additionthe speed of the art.pump motor can be regulated automatically by an electronic sensing unit.All parts which come into contact with blood are mounted on a removable base,which can be placed into an autoclave.Tygon tubing and pyrex glass are used for all connections.

For details of construction see the diagrams.

To date certain aspects of construction and design have not been satisfactorily worked out. These include: Antibubbling device for the collecting cup, distributing system for the jets, flowmeter, critical level control for use when operating arterial motor on the subject's arterial pressure. These will be described more completely under separate headings.

October 21, 1952

Effect of reducing body temperature on the clotting time of blood:

Purpose: To investigate The hypothesis that reducing the body temperature will prolong the clotting time of blood.

Procedure: 10 Kilo dog was anesthetized with 5 cc sodium nembutal I.V. and placed in a milk cooler at 5 degree C.

Time	Temp.	Clotting time
Control	38	10½ min
½ hr	34.5	3½ min
3½ hr	37,5	7 min

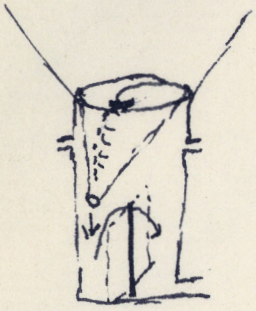
Comment: The body temperature was not lowered sufficiently to test the hypothesis. The dog shivered markedly throughout the experiment. It will be repeated using curare to prevent shivering.

November 4, 1952

Air embolism!

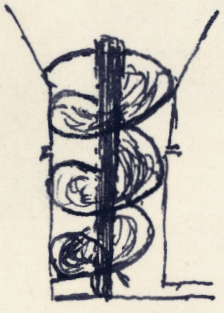
In process of trying out the new pump oxygenator with water it was noted that as the water flowed into the collecting cup numerous small and large bubbles of air were formed at the air-water interface and were carried down to the bottom of the cup and into the tubing to the arterial pumps. These observations were possible because the collecting cup is made of pyrex glass. Subsequently when blood was pumped through the machir the same phenomenon was observed. Inasmuch as the general construction of the tank and collecting cupon the old machine was the same as on the new, it must be assumed that bubbles were also formed in that machine. However, since the collecting cup on the old machine was made of enameled metal, these bubbles passed unnoticed. It is believed that air embolism occured in each perfusion and most likely was responsible for many of the deaths which occured.

Several metods of eliminating the bubbles were tried.



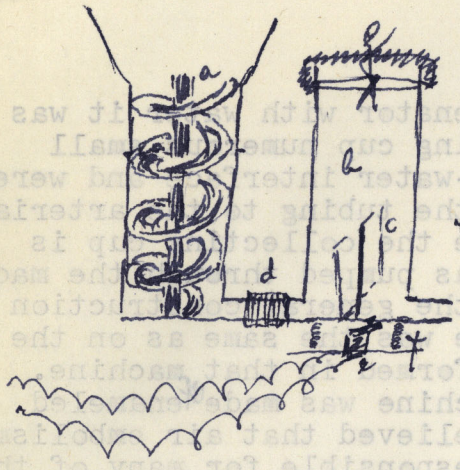
1.

1. Cone shaped funnel leading from the bottom of the tank to the side of the collecting cup plus a vertical baffle on the bottom of the cup. This arrangement was unsatisfactory because bubbles were still formed at the bottom of the cor cone and were carried over and under the baffle.

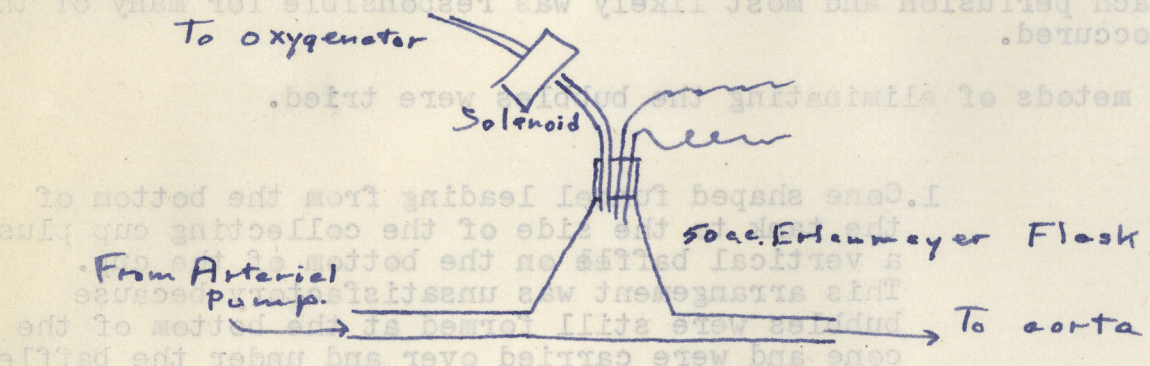


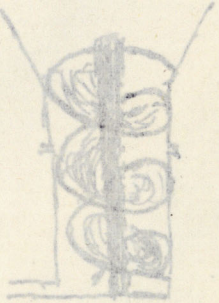
2.

2. Vertical spiral whose outer edges fitted closely with the wall of the collecting cup. This worked satisfactorily and it was decided to use it in the new machine. The blood level schould be maintained above the halfway mark.



3. Vertical spiral as in 2 plus a second collecting cup with vertical baffle.
The second cup was proposed as an added safeguard to prevent possible embolism. This would require an additional 300 cc of priming blood, but it is felt that the safety of the patient is more important than the cost of the operation. This device hasn't as yet been tried.





November 5, 1952

Filming studies on the 50 cm discs:

The machine was primed with freshly drawn heparinized dog's blood. The discs were revolved at varying speeds while the blood was pumped through the jets. It was observed that filming was satisfactory without additional measures such as sweeping the jets across the radius of the disc. At speeds below 48 RPM the blood flowed to the outer edge of the disc at 7 o'clock and off into the tank without spreading evenly over the disc. At speeds above 50 RPM filming was even but blood was hurled from the edge of the disc onto the tank and its cover. From these observations it would appear that the optimal speed of rotation is 48 RPM.

November 12, 1952

Distributor for DSK Pump Oxygenator

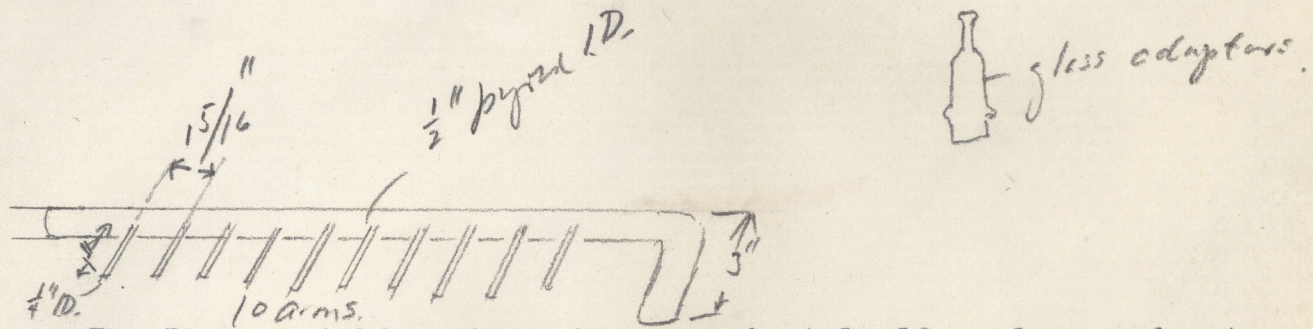
PURPOSE:

To develop a distributor for venous blood onto the discs in the oxygenator of the new DSK pump-oxygenator.

At the present time it has not been possible to develop cams which will deliver reliably a constnat flow of venous blood to the oxygenator screens. Because a uniform filming of blood on the screens is dependent on a relatively constant volume flow from each of the jets a method of obtaining a constant flow has to be devised.

Secondly, it was noted that if the venous blood flow was pulsatile, Blood drained out of the jet tubing during diastole, which caused greater mixing of air and blood and increased foaming.

METHOD:

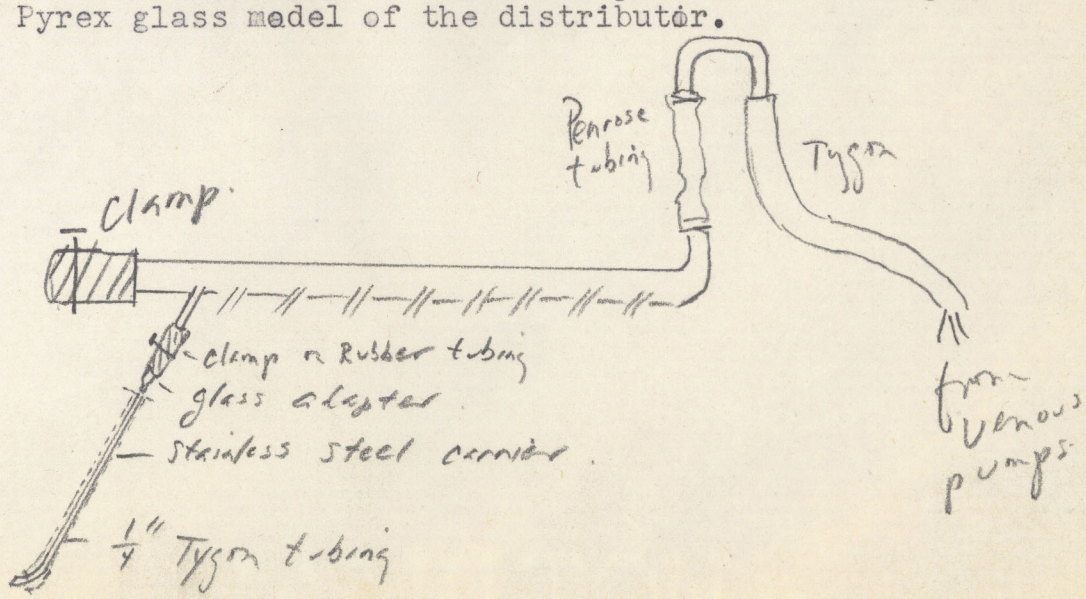


The Penrose tubing shown is approximately 10 cm long and acts as an elastic reservoir during systole and as a collapsable valve during diastole.

CONCLUSIONS:

Althoug this method did not produce a steady flow, it was a considerable improvement over direct streaming of blood rom the venous pumps. No air entered the jets tubing during diastole.

The impression was that this method did sufficiently satisfactory for use on the new machine and an order was placed with the glass blower for a Pyrex glass medel of the distributor.



November 12, 1952

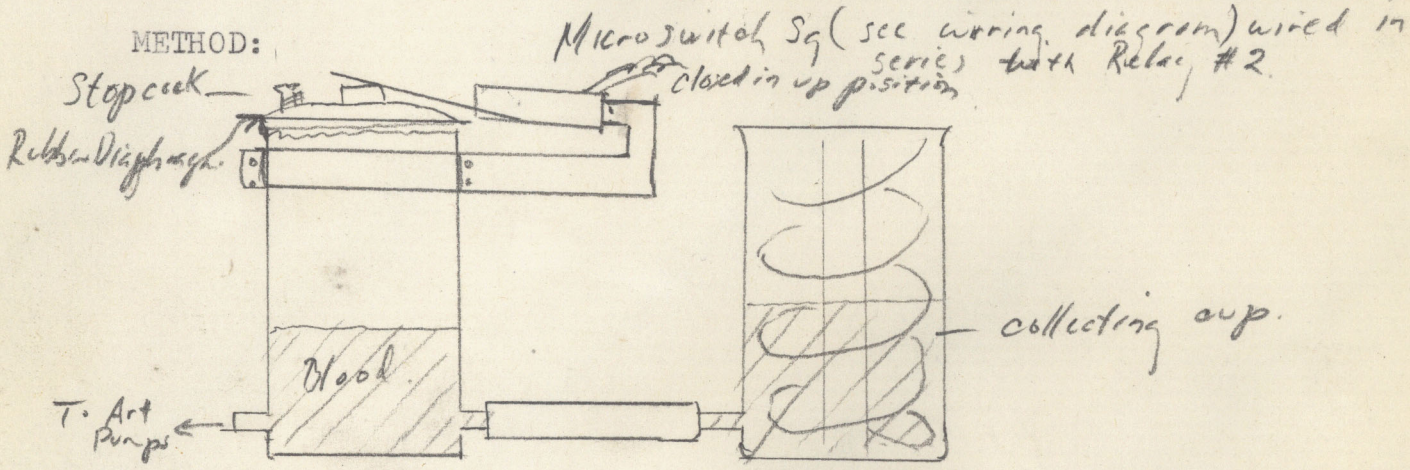
CRITICAL LEVEL CONTROL FOR DSK PUMP-OXYGENATOR

PURPOSE:

To develop a critical level stop for the DSK pump-oxygenator to prevent air embolism in the subject.

For the first perfusion on the new DSK machine, a method of automatically stopping the arterial pump motor when the level of blood in the reservoir fell to a low level had to be devised.

METHOD:



CONCLUSIONS: This apparatus is sufficiently reiable to be used with the machine for the first perfusion.

This apparatus is not a satisfactory secondary blood reservoir because the switch goes on and off with small changes in the level.

The stopcock can be used to admit more air and lower the level of the blood in the cup and use it as a manually controlled reservoir, although this is not a satisfactory method during an actual perfusion.

It was furthe noted that this apparatus acted as a secondary bubble trap during a perfusion.

While this apparatus requires too much blood for a critical level stop, it is sufficent for early perfusions on the machine. Dr. Dennis desires a method of having a critical level stop as well as a secondary blood reservoir in the same unit. Further thoughts along this line are needed.

November 14, 1952 Partial perfusion

Purpose: To test the new model of the DSKPump oxygenator for the first time. At the time of this experiment the permanent blood distributor was not available, and a temporary one was used. The arterial pump motor was controlled by the arterial pressure of the dog as described in protocol of 10/7/52. Critical level control as described on 11/12/52 using two collecting cups was used.

Procedure: Machine was assembled on 11/13 using Tygon tubing. It was than taken to E Building at KCH and autoclaved for 1/2 hr. Folloving autoclaving it was found that most of the connections wherein it had been necessary to stretch the tubing in order to slide it on to the glass or steel part, had split. Those connections which fitted easily were not affected by the heat. The split tubing was removerd and replaced c.unheated Tygon. Machine filled c.formaline as in the older model.

On 11/14 blood was drawn from two dogs using 1% procaine anesth. 3 mgm/Kg of heparine 15 minutes prior to doing cut down was administered. #3 liters of blood was obtained.

Suject dog: # 14 20 Kilo received MS gr.1/4 AS gr.1/50

Anesthesia: 10 cc Nembutal IV

Dog prepared and draped in the usual manner. Both femoral arteries and veins exposed. Left external jugular vein and left common carotid artery exposed. Extensive dissection was needed to expose this latter vessel. Five mgm./Kg heparin, for total of one hundred mgm administered. Common carotid cannulated and connected to the straingauge and to the arterial pump motor controlmechanism.

3:10 PM left external jugular cannulated with Polyethylene cannula BP 130/100

3:15 Right femoral vein cannulated

3:20 Femoral art. cannulated. BP125/120

3:31 Machine on, blood pressure dropped immediately to 15 mm Hg where it remained for 85 seconds. It was than noticed that there was a clamp on the arterial tubing. This was removed and the pressure rose instantly to 115/100.

3:38 100 cc blood transfused. BP rose to 150/125

3:43 BP 110/90 CO_2 flow increased to 500 cc /min.
50 cc blood transfused. 5 cc Neo-Syn given (1cc of NeoS in 100cc Gluc)

3:45 BP 150/125, venous return poor (no flowmeter)

3:48 100 cc blood transfused, BP 115/85. During this period the critical level control was hunting, turning the art. motor on and off at about 2 seconds intervalls.

3:51 Critical level controll still hunting.BP 125/80

3:53 Neo S drip on.BP 125/80

3:54 Neo S off.BP 125/80

3:55 Critical levelcontrol stopped hunting,BP 150/120

4:00 Arterial pump stroke decreased,BP fell to 125/100

4:02 Sensing unit potentiometer adjusted to give greater voltage from the phot cell.BP 110/100

4:05 Arterial stroke decreased, BP 75/70

4:06 5 cc of Neo S given,Bp 75/70

4:08 150 cc transfusion BP rose to 225/200

4:15 BP 175/170

4:20 BP 100/95

4:26 Venous pumps stopped

4:27 Arterial pumps stopped.BP rose to 180/160 and than gradually declined to 110/90 at 4:41 when the arter.pressure cannula was removed. 5,5cc Protamine given.

Inguinal and neck incisions closed. During the experiment there was considerable oozing of blood from the neck.This continued post op.

7:PMDog awake but does not move. 500,000 Un Crystacillin given

11:00 PM Dog alert,moaning, does not move, 500,000 Un.Crystacillin

Dog found dead on 11/15/52

Autopsy findings:
1. Considerable amount of blood arond neck wound
2. Petcchial hemorrhages on the mucosa of the small intestine similar to those seen in the syndrome of acute septicemia described by Dr.R. Nelson.
3. Dilatation of the right heart

Observations:

This perfusion schould be considered as an acute experiment because of considerable difficulties with the initial operation of the new machine.First of all there was difficulty with the autoclaving.After 45 min.the Tygon tubing on all tight fittings had split.Rubber washers on the pump heads softened and stretched under heat causing the intake valves to stick.This caused the regurgitation of blood back in to the collecting cup on the arterial side.
The machine had to be sterilised in the old fashion and this seamed to be inadequate.The Graham transmission motor failed to work just prior to starting the experiment and had to be hurriedly replaced.
Schortly after the start of the perfusion it was noticed that

the venous return was considerable than the output. The change of speed of the motor or stroke length on the venous side did not improve the situation. This may have been either due to the faulty position of one of the cannulas or to the use of cannulas with to small diameter.

The level in the collecting cup fell to the critical point and the arterial motor began to hunt. In order to eliminate this it was necessary to transfuse the machine and to decrease the stroke legth of the arterial pump.

The arterial pressure level control seams to work satisfactorily but since we coul not obtain adequate flows we can not decide whether or not it will be adequate for large flows e.g. 2500 - 3000 cc/min and more. It may prove necessary to change the arterial stroke volume during the procedure.

The by-pass unit had to be eliminated because of leakage.

Despite the large amount of heparin (100 mgm I.V. plus 120mgm in the donor blood) given to the dog there was a considerable amount of fibrin deposited in the machine especially on the spiral anti bubbling device. No one could remember siliconing this part.

There were no bubbles seen on the arterial side of the machine.

During the procedure extensive hemorrhage ossured from the neck incision. This passed unnoticed until the conclusion of the experiment. It was estimated that about 400 cc of blood was lost during the operation. Postoperatively the dog continued to ooze large quantities of blood from the neck wound. Whether the failure of the blood to clot was due to the acute septicemia which was noted on autopsy or to incomplete neutralization of the heparin could not be determined.

Conclusions:

1. Larger caliber (5/8") Tygon tubing must be obtained.

2. In order to test the art. pressure control system adequately satisfactory venous filling should be obtained either by a total perfusion or some other method.

3. By-pass to be made of stainless steel.

4. Spirals will have to be reconstructed and siliconed

Lab. data

Sample	Blood temp	pH	pH. Hgb	Hunter
Op conds	27°C	7.52	4.2 mgm%	49
Donor les	26.2	7.61	228	39
6 min	26.2	7.78	—	43
15 min	26.2	7.51	327	44
30 min	26.2	7.42	96	49
45 min	26.2	7.41	96	49
End 57 min.	26.3	7.59	42	42

Prot. Hb 25 gr/cc
total 5.5 cc

Formalin test: OK.

Dec. 17, 1952

Partial Perfusion, Acute Experiment

Purpose: To gain further experience in the operation of the new machine.

Procedure: 4000 cc. of donor blood drawn after giving 3 mg. of heparin per kg. wt. to the dogs. Pump-oxygenator not sterilized. Blood pressure control mechanism used. Critical level control operated manually.

Operative procedure: Femoral vessels exposed bilaterally. Chest opened Through third interspace(this was an error as it was intended to go through the 4th space). Right carotid artery exposed. Blood pressure control mechanism connected to the left femoral artery. Arterial return cannula inserted into carotid artery. Superior vena cava cannulated via azygos vein.

Time	Comment & Pressure
11:47	130 Arterial pump on.
11:48	130 down to 85. Venous pump on. Since the resevoir began to empty and the venous blood coming from the dog was taken up by the oxygenator screens, 1100cc. of blood was transfused into the resevoir. Pressure rose to 130.
12:00	100 cc. blood added because of low level in the cup. Pressure 135
12:10	Pressure 110. Neosynephrine (1 cc. of 1/1000 in 100 cc. saline) drip started. Pressure up to 190 then leveled off to 145 at 12:15 after stopping drip.

12:15 Machine off to check sensing unit. BP 125

L2:28 Machine on. BP up to 140 then Dropped to 100 and leveled off at 125. pH 7.30(uncorrected)

12:31 400 cc. blood removed from the resevoir. The clamp on the transfusion tube had not been tightened sufficiently and blood had been running into the resevoir unnoticed.

12:48 Machine off.BP 100. Ros e to 110 in 5 secs. and then leveled off at 105.

Observations:

1. The Machine operated very well.Blood pressure remained fairly constant at the desired level throughout, although it was necessary to give the dog 1200 cc. of blood to accomplish this. The initial drop in Pressure noticed when the machine was connected and turned on may perhaps be prevented by the prior administration of neosynephrine.A method will be devised to operate the transfusion of blood into the resevoir automatically by means of a solenoid on the tube.

2. New shuttle valves were used on the output sides of the pumps and functioned efficiently.

3. The cams followed the cam riders very wellwithout springs, since the opening between the bottom of the pump head and the hose connection to the bellows had been enlarged.

Total Perfusion 12/29/52 no flow
P

Purpose: To investigate the feasibility of using a dog's lung as an oxygenator.

Method: Non-sterile technique used. Two donor dogs exsanguinated after heparinization. The second dog's chest was opened post-mortem and the lungs and heart removed. Superior and inferior venae cavae and aorta tied. Specimen placed in pan. Venous pump outlet tube of DSK machine Connected via cannula to pulmonary artery. Left atrium connected to collecting cup via tube. Arterial motor controlled bysubject's blood pressure. Transfusion bottle connected to collecting cup. No flowmeter in circuit.

Procedure: 16 Kg. dog anesthetized with 8 cc. sodium nembutal I.V. M.S. and atropine ¼ and 1/50 gr. respectively given. Chest opened via incision in 3d interspace, extending across entire anterior chest wall.Arterial cannula placed through left subclavian artery into aorta. Venous cannulas into superior vena cava through azygos v. and inf. vena cava through rt. auricular appendage.Rt. femoral art. connected to strain gauge and arterial pressure control system. Dog given 48 mg. heparin i.v. Infusion of normal saline started in rt. fem. vein.

Time	Comment
12:29	Rt. fem. artery cannulated. BP 100/95
12:33	BP varies with respiration from 110/105 to 100/95
12:41	Cann. in lt. subclavian artery. BP 120/115
12:58	SVC cann. in place. BP 110/ 105
1:14	BP 115/110
1:25	Bp 125/110
1:26	Arterial pump on.BP 125/110. BP rose to 205/175 in 40 secs. at which time the venous motor was turned on. At this point the the arterial pump motor began to hunt, being turned off when the BP hit about 175 and starting when it fell to about 150. This produced a blood pressure curve similar to that produced by the respiratory movements of a normal dog.
1:30	Arterial stroke decreased. BP stabilized at 115/110 as hunting ceased.
1:32	BP 105/95
1:36	Arterial stroke decreased because of hunting. BP fell 170/160 to 95/90 in 30 secs.
1:38	IVC cannula opened.BP 120/110. Venous stroke increased.
1:40	BP 125/115
1:41	IVC tied about cannula. BP 135/125
1:43	SVC tied. BP 150/140
1:45	BP varies from 160/150 to 90/85 because of hunting.
1:46	100 cc. blood transfused. Pressure stabilized at 130/125 for 1 minute , then hunting began again at that BP level. Another 100 cc. blood given.
1:48	BP 75/70. 100 cc. blood given.
1:49	BP 115/110
1:51	BP 95/85

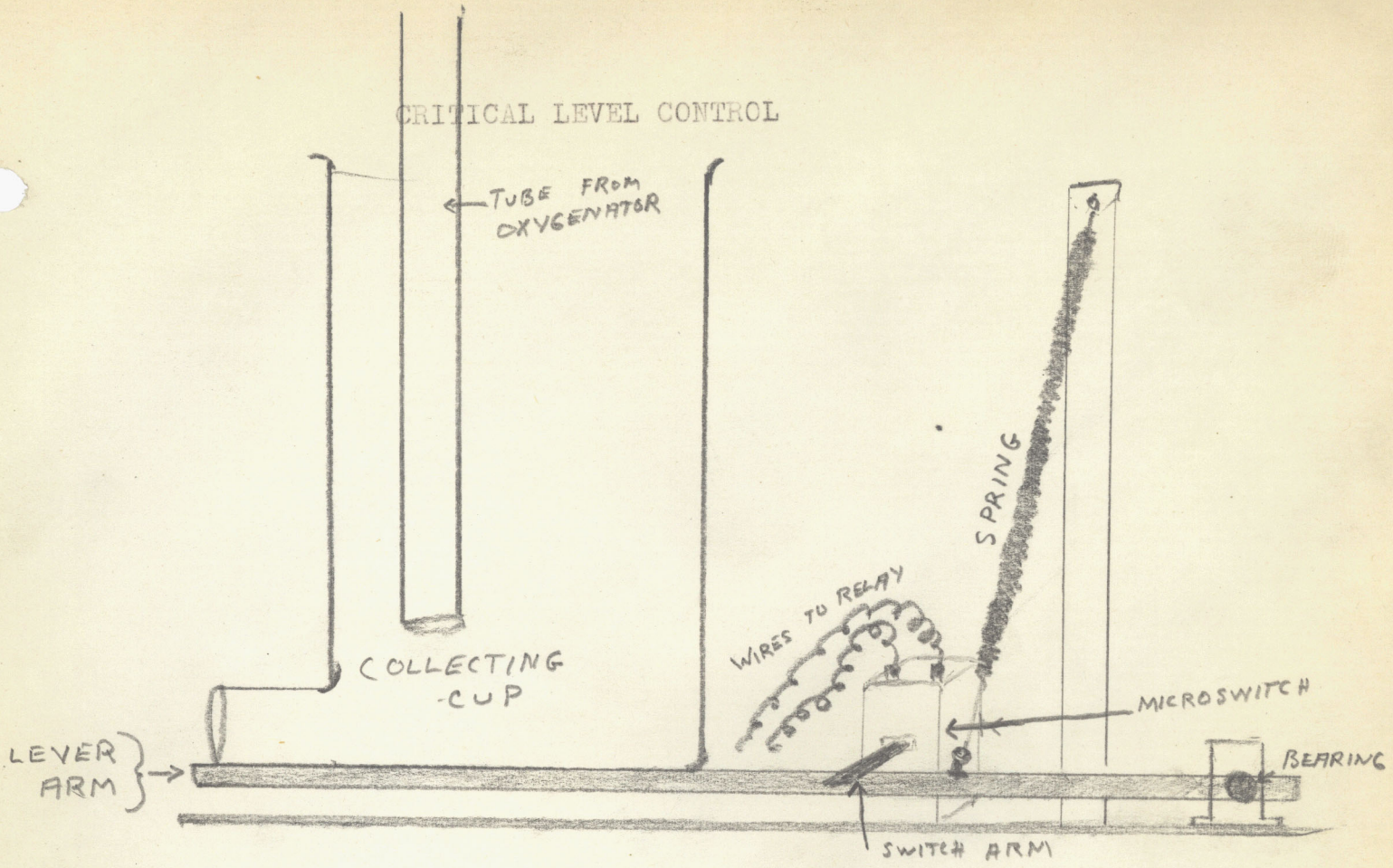
1:52 Arterial stroke increased. BP rose to 140/130
1:54 BP 115/90. Neosynephrine drip (1 cc. neo. 1:1000 in 50 cc. saline) started.
1:56 BP 105/100. Stable for next 10 minutes.
2:05 BP 130/120. 50 cc. blood given.
2:06 Ties off cavae. IVC. tube clamped.
2:07 BP 150/140. Cann. removed from rt. atrium. Protamine started.
2:08 SVC. tubing clamped. BP 145/130.
2:09 SVC. cann. removed. BP same.
2:10 Pump off and cann. out of subclavian artery. BP 160/140
BP remained stable until the chest was closed and the respiretor was detached from the endotracheal tube.
2:38 BP 115/95. Pressure then gradually declined to zero at 3:00. Chest opened rapidly and heart massaged. Digitalis given but to no avail. Dog expired at 3:10.

OBSERVATIONS.

1. Oxygenation appeared to be good, although the venous blood appeared very dark, suggesting poor blood flow.

2. An estimation of blood flow was made by clamping the arterial cannula and allowing blood to accumulate in the collecting cup over a period of 10 secs. The increased volume in the cup was measured. Max. flow obtained was 600 cc./ min.

CRITICAL LEVEL CONTROL



1. The poles on the microswitch were reversedso that the motor runs when the switch is open.
2. When the cup is filled the weight of the blood depresses the lever arm which in turn opens the microswitch allowing the arterial motor to run.
3. If the level of the blood falls the weight of the cup decreases. When the critical point is reached, the spring causes the lever to rise, closing the switch and stopping the motor.
4. As blood continues to enter the cup , the lever falls, the switch opens and the motor starts.

TOTAL PERFUSION 12-31-52

Purpose: To test once more the feasibility of using a lung as an oxygenator.

Method: The same procedure was followed as on 12-29, except that the oxygenated blood from the pulmonary veins of the donor heart lung systemwas allowed to drip freely into a tank. From here it was led through rubber tubing into the collecting cup. Only one lung was used, the branches to the other lung having been ligated as in the method of Dr. Mustard. A flowmeter was placed in the circuit on the arterial side. Non-sterile technique used. 8 Kg. dog. Heparin, 3mg/kg. given just prior to insertion of cannulae.

Procedure:

TIME	COMMENT
11:45	Cann. in aorta through lt. subclavian artery. BP110/100
11:50	SVCcann. in place. BP 115/110
12/10	Machine on. BP 95/85.
12/12	BP 85/80. 150 cc. blood transfused.
12/15	BP 85/80. 1200cc blood/min. flow.
12/16	BP 50/45. 200 cc. blood given.
12/17/60	BP 65/60. 100 cc. blood given.
12/20	Rt. atrium dissected. Bp. 100/90.
12/22	Auricular appendage incised. BP 105/100.
12/23	In passing the cannula through the right auricle into the inferior v na cava, a hole was punctured in the posterior wall of the cava, just caudal to its juncture with the atrium. BP fell to 60/55. The hole was clamped with a Mixter forceps, and closed with a continuos 0000 silk suture. Some leakage of b;ood persisted and the suture line was again grasped with a Mixter forceps and a twill tape ligature was placed below the clamp. This effectively controlled the bleed-

ing.

12/28 BP 35/25. 250 cc. blood given.

12/29 100 cc. blood. Bp 50/45. IVC. cann. removed.

12/29½ 75 cc. blood. BP 75/65.

12/30 75 cc. blood. BP 85/75. IVC. hole repaired.

12/34 BP 85/80.

12/42 Dog expired.

On examining the heart post-mortem, it was found that the coronary sinus had been occluded by the twill tape ligature. The heart had begun to enlarge immediately after the tie had been placed. Auricular fibrillation and death followed shortly.

The hole was made because the short sive of the cannula used made accurate direction into the IVC, difficult. It apparently caught in the opening of the coronary sinus, then slipped out suddenly and punctured the wall of the IVC.

The dog was never totally perfused, as the IVC. cann. was never connected to the machine.

Outside diameters of the cannulas used:

IVC-.300
SVC-.250
ART.-.185